

**Population Dispersal, Size, and
Interactions of Harbour Porpoises in the
Bay of Fundy and Gulf of Maine**

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POPULATION DISPERSAL SIZE, AND INTERACTIONS
OF HARBOUR PORPOISES IN THE
BAY OF FUNDY AND GULF OF MAINE

by

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ABSTRACT

Gaskin, D. E., A. J. Read, P. Watts, and G. J. D. Smith. 1985. Population dispersal, size, and interactions of harbour porpoises in the Bay of Fundy and Gulf of Maine. Can. Tech. Rep. Fish. Aquat. Sci. 1291: 28p.

Several methodological approaches were used to examine various aspects of the harbour porpoise population in the Bay of Fundy-Gulf of Maine region between July 1981 and September 1983. Eight porpoises were captured, radio-tagged (172-173 MHz) and released during this period. In most cases, the tracking period of these porpoises was too short to establish seasonal ranges of annual migration routes. The seasonal range of one porpoise, tracked for 22.4 d, was estimated as 210 km². Habitat index analysis indicated a positive correlation between harbour porpoise abundance and both increasing depth and physiographic features which concentrate herring, and a negative correlation between abundance and mean August surface temperatures. These correlations may reflect the tendency of porpoises to utilize areas of high prey (herring) density. Strip transect surveys throughout the study area yielded a minimum population estimate of 3056 porpoises in the western Bay of Fundy during late July and August 1981. The results of a survey of weir fishermen in the study area indicated that approximately 1% of the minimum population estimate are killed each year after becoming trapped in herring weirs. Gill nets throughout the range of the population pose a more serious threat than herring weirs, as there is little opportunity for live release. We support a conservative approach to managing this population, especially in light of the recent collapse of two European populations of this species.

RÉSUMÉ

Gaskin, D. E., A. J. Read, P. Watts, and G. J. D. Smith. 1985. Population dispersal, size, and interactions of harbour porpoises in the Bay of Fundy and Gulf of Maine. Can. Tech. Rep. Fish. Aquat. Sci. 1291: 28 p.

Plusieurs méthodes ont été utilisées pour étudier divers aspects de la population de marsouin commun fréquentant la baie de Fundy et la golfe du Maine entre juillet 1981 et septembre 1983. Huit marsouins ont été capturés, munis d'un émetteur radio (172-173 MHz) et relâchés pendant cette période. Dans la plupart des cas, la durée du dépistage était trop courte pour établir l'aire de répartition saisonnière au cours de la migration annuelle. Pour un marsouin particulier suivi pendant 22,4 d, cette aire a été estimée à 210 km². Une analyse de l'indice relatif à l'habitat a révélé une corrélation positive entre, d'une part, le nombre de marsouins communs et, d'autre part, un accroissement de la profondeur et les caractéristiques physiographiques entraînant des concentrations de hareng; de plus, on a observé une corrélation négative entre le nombre de marsouins et les températures moyennes à la surface en août. Ces corrélations peuvent traduire la tendance des marsouins à utiliser les zones de densité élevée de proies (hareng). Des levés par transects en bande effectués dans toute la zone expérimentale ont fourni une estimation minimale de 3 056 marsouins dans la partie occidentale de la baie de Fundy à la fin juillet et en août 1981. Les résultats d'une enquête menée auprès des pêcheurs exploitant des parcs en filet dans la même zone ont révélé qu'environ 1 % de ce nombre sont tués chaque année après s'être enchevêtrés dans les filets à hareng. Dans toute l'aire de répartition de la population, les filets maillants posent une menace plus sérieuse que les filets à hareng car il existe peu de chance de relâcher les animaux vivants. La gestion de cette population devrait, selon les auteurs, faire l'objet d'une approche prudente surtout quand on considère l'effondrement récent de deux populations européennes de la même espèce.

PREFACE

Our research group has conducted extensive seasonal investigations of the harbour porpoise population in the Bay of Fundy since 1969. However, the unobtrusive nature of the species, combined with logistical constraints, have hampered definitive studies of the range, dispersal and size of this population. The research contract awarded to the University of Guelph by the Departments of Supply and Services and Fisheries and Oceans (DSS Contract UP-G-152) allowed the investigation of these parameters during the period May 1981 to October 1983.

We thank Dr. W. G. Doubleday (Resource Research Branch, DFO), the Scientific Authority responsible for administration of this contract, for his assistance in all phases of this project.

INTRODUCTION

Recent evidence indicates that several populations of the harbour porpoise (*Phocoena phocoena*), particularly those of the Baltic and Black Seas, are seriously depleted (Gaskin 1984). Concern has also been raised regarding the status of the population in the Bay of Fundy-Gulf of Maine region. This report summarizes the results of a preliminary assessment of the harbour porpoise population in this area.

Assessment and monitoring of harbour porpoise populations requires relatively accurate estimates of population size, range, age structure, mortality, and recruitment. Only when these basic population parameters have been satisfactorily defined may we assess the nature and extent of human impact on a particular population.

The primary objectives of the present study were:

1. To examine summer feeding ranges of harbour porpoises utilizing the western Bay of Fundy. While a considerable amount of data on relative abundance has been gathered in the last 15 years (Gaskin 1977; Gaskin and Smith 1979; Prescott *et al.* 1981), little is known of the daily and seasonal movements of individual porpoises. An earlier study of distribution and dispersal provided limited evidence that harbour porpoises exhibited some degree of foraging range during the summer months (Gaskin *et al.* 1975).

2. To refine a quantitative index of habitat utilization. A preliminary study in which habitat index equations were applied to harbour porpoises near Deer Island, New Brunswick, successfully defined relationships between abundance and several environmental factors (Smith and Gaskin 1983). This study concentrated on mother-calf pairs, however, and was based on data not originally intended for such analysis. The application of habitat index techniques to other social categories of porpoises using standardised data seemed a logical extension of this original research. The development of such an index provides the potential for estimating porpoise density on the basis of habitat type.

3. To improve existing population estimates for the western approaches to the Bay of Fundy, and compare densities in different areas to gain further insight into habitat utilisation. The only existing population estimates for

the Bay of Fundy are those of Gaskin (1977) and Prescott *et al.* (1981). Gaskin's estimate was based on very approximate census results, while that of Prescott *et al.* (1981) was derived from aerial surveys where the sighting efficiency was estimated as 14%. Relative abundances in the study area have been shown to vary widely, with high concentrations in certain sectors (Gaskin and Smith 1979).

4. To collect and assess information on the nature and magnitude of incidental catches of harbour porpoises in the Bay of Fundy. Observations made in previous years indicated that porpoises are incidentally taken in both herring weirs and groundfish gill-nets, although the level of this by-catch is unknown.

THE STUDY REGION

INSHORE STUDY AREAS

The three inshore study areas selected for detailed examination during this study (Figures 2-4) provided a wide variety of potential habitats for harbour porpoises, containing a broad range of depth, topography, current velocity, and upwelling (Forrester 1958; Smith *et al.* 1984). Previous observations indicated that, although harbour porpoises were abundant throughout the region (Sergeant *et al.* 1970; Gaskin 1977), consistent and distinct differences in density would exist within each area (D.E. Gaskin, unpubl. data).

The Deer Island archipelago (Figure 2) is by far the most diverse of the three inshore areas. The deepest waters encountered during the inshore portion of the study (greater than 100 m) occur here, both in high velocity (greater than 2 m.s⁻¹) channels, and in quieter (less than 1 m.s⁻¹) localities. Upwelling and rip zones are common in deep, fast water, but unlike the Grand Manan and Digby areas, such oceanographic activity is also commonly associated with swift currents and rugged topography in shallower waters (less than 10 m deep). Between these extremes lies water of intermediate depth in which currents are weaker (less than 0.5 m.s⁻¹), although some upwelling still occurs. The close proximity of such diverse physical and dynamic features is associated with a wide variety of inshore habitats. Thus, the Deer Island area probably supports the greatest concentration of harbour porpoises in the inshore waters of the Bay of Fundy (Gaskin 1977).

The Grand Manan area (Figure 3) has somewhat less topographic diversity. Shallow waters are often steeply contoured, although deeper water is often associated with low topographic variability. Waters near Grand Manan are as deep as 100 m, with tidal currents approaching 3 m s^{-1} . The island mass splits the incoming tidal current into two strams which, on the flood tide converge in a shear zone off the northern tip of Grand Manan. This creates a conspicuous deep-water area of rip and upwelling where seabirds and porpoises congregate (Read 1983).

The Digby area (Figure 4) is the least physiographically complex of the three inshore areas. It consists of the shallow (less than 25 m deep), enclosed Annapolis Basin and the Digby Gut, a high current velocity channel approximately 50 m deep. Both areas are topographically monotonous. Tidal currents range up to 2.6 m s^{-1} in the Digby Gut, and are somewhat less in most parts of the basin. Despite the high velocity of tidal currents in the channel, the major flow in this part of the Bay of Fundy sweeps past the mouth of the Gut. The amount of water entering the Gut is limited by its perpendicular orientation to the main current and by its relatively shallow depth.

OFFSHORE STUDY AREAS

The offshore areas considered in this study include the Outer Quoddy Region as defined by Trites (1979) and the western approaches to the Bay of Fundy, from Grand Manan to the approximate mid-line of the Owen Basin (Figure 1). Except for one survey to Brier Island, Nova Scotia (1981) and another to the Grand Manan Banks (1983), limitations on funding and travel time restricted surveys to the western Bay of Fundy.

The outermost study regions are not topographically complex; the sea floor slopes gradually east of Grand Manan, except for the precipitous scarp off the southeast of the island, outside the Old Proprietor ledges. The floor of the Grand Manan basin is relatively flat, rising gently towards the upper coast of the Digby neck, but very sharply towards the lower region of Long and Brier Islands. Above the scarp ridge are a series of peaks which form shallow ledges along that part of the Nova Scotia coast. Both here, and off the Old Proprietor, the tidal flow is strong and brings up cool sub-surface water in a series of small scale upwellings, which drift downstream, sinking in a

series of tide streaks or miniature convergence zones (Brown 1980). These streaks, especially at the margins, contain large concentrations of copepods and euphausiids at or near the surface. The mechanisms of concentration may be related to Langmuir cells in the case of the copepods, but the situation is less clear where the euphausiids are concerned (Brown *et al.* 1979). The zooplankton concentrations attract herring, mackerel, and seabirds; the fish, in turn, attract harbour porpoises and white-sided dolphins (Lagenorhynchus acutus) in both areas.

Several readily discernible streaks also exist offshore along the longitudinal axis of the Bay of Fundy, spaced several kilometers apart east of Grand Manan. Harbour porpoises are associated with the two inner streaks, as well as having a general distribution along the turbulent zone of the Grand Manan inshore belt, with concentrations off the southeast shoals and the region to the north of the island. Right whales (Eubalaena glacialis) are associated with the outer-most streak, indicating that it may be of different character than the others; it is close to the transition zone indicated by Greenberg (1979). Near-surface salinities and temperatures are consistently higher during the summer and fall in the offshore portion of the study area than in the inshore areas, and the water column is somewhat more stable.

MATERIALS AND METHODS

RADIO TRACKING

Radio tracking techniques were used to monitor the movements of eight harbour porpoises over the course of the study. Porpoises were seined from herring weirs, where they had become accidentally trapped, and placed in small boats where the radio transmitters were attached. The transmitters, attachment procedure and receiving system are described in Read and Gaskin (1983).

The position of each radio-tagged porpoise was determined at least once a day, but usually on a more frequent basis. The position of a tagged porpoise was determined either by tracking the animal until visual contact was established, or by triangulation from land. Each sighting or radio location (derived by triangulation) was assigned to a 1 km grid square of the Universal Transverse Mercator (UTM)

System.

HABITAT INDEX

Three areas were chosen for intensive study: the waters around Deer Island and Grand Manan Island, New Brunswick and the Digby Gut, Nova Scotia (Figures 2-4). In each area, a series of 5 km transects was selected to maximize the range of habitat types under examination. Four transects were originally chosen from the Deer Island area, three from Grand Manan, and two from Digby. After preliminary analysis of the 1981 results, a fifth Deer Island transect was added to increase the range of water depths sampled in this area. This transect was surveyed only in 1982; all others were sampled in both 1981 and 1982.

To maintain constant sighting efficiency, transects were run only under conditions of unlimited visibility and wave height of less than 30 cm (Beaufort Sea Scale 0 or 1). The small vessels used for these inshore surveys ensured that transects were run only under ideal conditions.

During transect runs, observers scanned a 180° arc ahead of the vessel. Upon making a contact, the sighting angle (0° lying directly ahead) and radial sighting distance were estimated and recorded. All estimates of sighting distances were made visually. These estimates were accurate to ±15 m at 100 m range, using readings from a stereoscopic rangefinder as a standard. The rangefinder could not be used to determine actual sighting distances because of the brief and intermittent nature of the sightings.

All porpoise sightings were recorded regardless of range. This allowed expression of the data in relative terms of "sightings per hour" (see Smith and Gaskin 1983), and permitted an index to be based upon the maximum available data. By plotting sighting frequency against perpendicular distance from the transect line, and by determining the distance beyond which sighting efficiency decreased, it was also possible to derive a strip transect as a basis for preliminary population estimates (Eberhardt 1978). The frequency of sightings decreased by over 50% beyond a perpendicular distance of 25 m from the transect line (Figure 5); therefore the derived strip was 50 m wide.

In addition to harbour porpoise sightings, twelve environmental variables were measured along each

transect. These were:

- Depth at low water
- Bottom topography index (Hui 1979)
- Maximum current velocity
- Herring entry points
- Tidal amplitude
- Period of tidal cycle
- Surface water temperature
- Percentage upwelling
- Percentage rip
- Average wave height
- Boat activity
- Lateness of season

Explanation of these environmental variables, and further details of transect methodology and preliminary data analysis may be found in Watts and Gaskin (1984).

POPULATION ESTIMATION

Because the assumption of a homogeneously distributed harbour porpoise population is unrealistic, the study region was stratified on the basis of information accrued on an opportunistic basis between 1969-1980, and the densities in particular areas examined separately.

As mentioned above, the transects used to develop the habitat index were also used to provide information on the densities of porpoises in the inshore areas of the study region. Transects in these inshore areas were conducted in 1981 and 1982.

Observers also conducted regular porpoise surveys from the ferries which run between Grand Manan and mainland New Brunswick. These surveys were run along a 31 km transect from Pea Point Lighthouse (mainland N.B.) to Swallowtail Lighthouse (Grand Manan), during 1981, 1982 and 1983. The methodology utilized in these surveys was similar to that employed during inshore transects (see Habitat Index). A single observer was situated approximately 6 m above the water's surface on the passenger deck of the ferry. The configuration of the superstructure did not allow efficient observation of a 180° arc ahead of the vessel, and it was seldom possible to employ an observer on each side. It was decided, therefore, to scan a 90° arc to one side of the line of travel and keep separate records for the east and west sides of the ferry route. Mean time for completion of a survey was 95 min.

In addition to the inshore transects and observations from the ferry, surveys were also conducted from

two chartered vessels, the 13.7 m MV "Miss Michelle" (Huntsman Marine Laboratory) and the 12.8 m MV "Pat & Robbie" (Ocean Search Ltd.). Vessel speed ($15\text{ km}\cdot\text{h}^{-1}$) and observer height (2.5 m) were similar for both vessels. The methodology used by observers aboard these vessels was similar to that employed during inshore transects.

The Outer Quoddy region was surveyed by observers aboard the MV "Miss Michelle" on three days in late July and early August 1983. These surveys were conducted to examine any potential biases imposed by the use of the ferries for estimating porpoise density in this area. A series of transects were selected one km apart, running in an east-west orientation (approximately perpendicular to the ferry route) (see Figure 6). On each survey day, a number of transects was selected randomly (without replacement) from the available pool.

The offshore waters to the east of Grand Manan Island were surveyed by observers aboard the MV "Pat & Robbie" during the summer months of 1981 and 1983. These surveys were of an opportunistic nature and did not follow specific transect lines. However, in all other respects the methodology employed during these surveys was similar to that employed aboard other vessels.

The effective strip width was calculated separately for each class of vessel. As previously mentioned, the strip width used in the inshore transects was 50 m (see Habitat Index). The calculated strip width for the MV "Pat & Robbie" and MV "Miss Michelle" was 100 m (50 m on each side of the transect line) and the strip width for the Grand Manan ferries was 200 m. This variation in strip width no doubt reflects the differences in observer height between the three classes of vessels. Once corrected for strip width, each survey represents a long narrow sample of the study area, and may be used to estimate densities of porpoises in adjacent areas (Eberhardt *et al.* 1979).

INCIDENTAL CATCHES

Since no formal reporting system for incidental catches of marine mammals exists in Canadian waters, we attempted to assess the annual incidental catch of harbour porpoises by interviewing commercial fishermen. Questionnaires were mailed to all 214 members of the Fundy Weir Fishermen Association in 1980. A total of 36 usable

questionnaires (16.8% of the total) were returned. In addition, informal interviews were conducted with fishermen involved in the groundfish gill-net fishery in 1981, 1982 and 1983. Further details of the methodology used to assess the rate of incidental catches is presented in Smith *et al.* (1983).

RESULTS

RADIO TRACKING

Over the course of the study, eight harbour porpoises were radio-tagged and two small porpoises were fin-tagged and released (Table 1). In addition, we received reports of ten other porpoises which had become trapped in weirs during this period. The majority of these animals escaped or were released before we could initiate tagging procedures.

During the transmitter attachment procedure, porpoises were out of the water for a mean of 6.6 min ($SD = 1.4$, $n=8$), during which most animals remained fairly still. Only two porpoises exhibited any trauma while out of the water; RT-5 vomited briefly, and RT-7 (a 110 cm calf) repeatedly lashed its flukes. The latter porpoise appeared momentarily disoriented when returned to the water, but quickly resumed swimming and surfacing normally after being joined by an adult porpoise. The larger animal, presumably the calf's mother, had also been trapped in the weir, but escaped overnight and remained in the vicinity until the calf's release.

The duration of radio contact with tagged porpoises ranged from 0.30 d (RT-5) to 22.4 d (RT-2), with a mean of 5.1 d ($SD = 7.1$, $n=8$). In some instances, loss of contact may have been due to the premature release of the transmitter package; the rear bolt attaching the transmitter to the dorsal fin of RT-3 was missing when this porpoise was photographed five hours before signal loss occurred. The radio signals of RT-3 and RT-7 were being monitored when contact was lost, and in both cases the signal loss was abrupt, a pattern compatible with the hypothesis of transmitter loss. It is also possible that transmitter failure accounted for some occurrences of signal loss.

Direct observations made after release and monitoring of ventilation patterns gave no indication that the transmitter packages affected the behaviour of tagged porpoises. In all cases, sightings of radio-tagged animals

indicated that the behaviour of tagged animals was similar to that of other porpoises in the area.

The longest radio tracking sequence recorded in this study was that of RT-2 (Table 1). This porpoise spent the majority of its 22.4 d tracking period within Passamaquoddy Bay, although occasional excursions were made to the east of Deer Island (Figure 8). The home range of RT-2, calculated using the convex polygon method (Mohr 1947), was approximately 210 km² (excluding land masses). RT-2 rarely visited the northern and eastern portions of Passamaquoddy Bay, although the central and western regions were extensively utilized.

The movements of RT-2 were representative of the results recorded from other radio-tagged porpoises. Although radio-tagged animals demonstrated considerable mobility (often moving 15-20 km in a 24 h period), there was no evidence indicating that porpoises left the study area during their respective tracking periods. The movements of these porpoises suggest that considerable interchange occurs between the Grand Manan and Deer Island areas. A detailed description of these results may be found in Read and Gaskin (1984).

On seven occasions, the movements of radio-tagged porpoises were tracked through the major channels and passages of the Deer Island area. In all cases, the direction of movement coincided with the direction of tidal flow. The strong correlation between porpoise movements and current direction was demonstrated on 30 August 1981, when RT-2 moved up Western Passage with the flood tide, turned at slack high water and moved out with the ebb. Tidal flow may have also affected the movements of radio-tagged animals in the waters near Grand Manan; all three porpoises released at low water in Whale Cove moved north with the flood tide (see Read and Gaskin 1984).

Attempts to relocate radio-tagged animals illustrated some of the inherent problems involved in censusing harbour porpoise populations. Even with the aid of directional receivers and brightly painted transmitter packages, it was difficult to see radio-tagged porpoises while they lay motionless at the surface.

HABITAT INDEX

A total of 415 harbour porpoise sightings were recorded during the inshore portion of the study. Depth,

the dummy variable representing herring entry points (H), and mean August surface water temperature were the only time-independent variables which were significantly correlated with harbour porpoise sightings. There was evidence that the lateness of season and period in the tidal cycle were also related to porpoise sightings, but since the data were pooled for further analysis, such temporal effects were masked and had to be analyzed separately (see Watts and Gaskin 1984).

The sighting data for each transect were averaged over both seasons (1981 and 1982) and regressed against depth, H, and mean August surface temperatures. The resulting equations took the form:

$$Y_1 = 0.0447D + 4.10H - 0.159 \quad (1)$$

$$Y_2 = 0.0139D + 1.95H - 0.169T + 2.15 \quad (2)$$

where Y_1 is mean sightings per hour, Y_2 is mean sightings per km², D is depth, T is mean August surface water temperature, and H represents the herring entry points. Adjusted r^2 were 0.972 for Equation 1 and 0.986 for Equation 2. Both equations were highly significant ($p < 0.0001$).

Neither equation suffers from significant bias, non-normality, inconsistent variance, or multicollinearity. Further discussion of the development of these equations and their underlying assumptions may be found in Watts and Gaskin (1984).

POPULATION ESTIMATION

The majority of the harbour porpoise population appeared to arrive in the study area during mid-July each year (Read 1983). To avoid any seasonal bias, therefore, only surveys conducted after 15 July have been included in the calculation of porpoise densities.

As previously mentioned, the transects used to generate data for the habitat index were also used to obtain information on harbour porpoise densities in the Deer Island and Grand Manan areas. In 1981, a total of 79 transects (395 km of survey trackline) were run in the inshore waters of these two areas. In 1982, 73 transects (365 km of trackline) were completed. The porpoise densities observed along these transects are presented in Table 2. The density of porpoises in areas not covered by these transects was estimated by applying densities from adjacent and similar habitats (Figures 2 and 3), based on information accrued from 1969-1980 (see Smith and Gaskin (1983)).

During the three years of the study, 29 surveys were conducted from the Grand Manan ferries in the Outer Quoddy region, covering 904 km of trackline. A total of 593 porpoises were sighted within the 200 m strip, including sightings of 62 calves (10.4% of the total). Little variation was evident in the observed harbour porpoise densities between the three years (Table 3).

The Outer Quoddy region was also surveyed by observers aboard the MV "Miss Michelle" which completed 14 transects (over 168 km) during late July and early August 1983 (Table 4). The density estimate generated by these observations is similar to that calculated from 1983 ferry surveys (3.38 and 3.48 porpoises km^{-2} , respectively). In addition, 37 km of survey trackline was completed from the MV "Pat & Robbie" on 04 August 1983 in this region. This survey yielded an observed porpoise density of 3.51 porpoises km^{-2} , similar to that observed from the other two vessels.

The offshore portion of the study area was surveyed on four days in 1981, covering 234 km of trackline (Figure 7). In 1983, this area was surveyed on eight days, covering 490 km of trackline (Figure 7). The observed porpoise densities in this area were 1.15 porpoises km^{-2} in 1981, and 1.10 porpoises km^{-2} in 1983.

Observed porpoise densities were applied to each region of the study area (Figures 2, 3 and 9) to estimate the total population size for the entire area. Inshore transects were not conducted in 1983 and the offshore area was not surveyed in 1982, so it was possible to generate an estimate for the entire study area only in 1981. The estimates for each region are summarized in Table 6.

INCIDENTAL CATCHES

Questionnaire returns indicated that approximately 70 harbour porpoises become trapped in New Brunswick herring weirs each year. Of these animals, 39% are either shot or drown accidentally during attempts to remove them. The remaining animals were described as being released alive or finding their own way out of the weirs. It is interesting to note that of 48 specimens examined from weirs during the period 1969-1980, over half (52%) were yearlings (see discussion in Smith *et al.* 1983).

During the present three-year study

(1981-1983), we were notified of twenty harbour porpoises trapped in herring weirs. Ten animals were tagged and released, four escaped without assistance and one was released by a fisherman. The fate of the other five porpoises is unknown, but it is likely that at least some of them were shot. In addition to the porpoises, three minke whales (*Balaenoptera acutorostrata*) and one humpback whale (*Megaptera novaeangliae*) became trapped during this period. All of the whales were released unharmed.

Although over 500 gill-net licences were issued in the region (P. Hurley, DFO, St. Andrews, pers. comm.), only a handful of groundfish gill-netters seemed to be in operation in the study area. If reports from fishermen were accurate, the annual incidental catch by this fishery varies from 0-15 porpoises per year. Four specimens were obtained in 1981, a single animal in 1982, and eight obtained in 1983. Three more porpoises were reported but discarded in 1983. It appears that few gill nets operate elsewhere in the study area, although the New England Aquarium obtained one animal in 1982 from Head Harbour Passage which appeared to have died as a result of net entanglement (S. Kraus, NEA, pers. comm.).

DISCUSSION

RADIO TRACKING

In general, the duration of contact with radio-tagged porpoises was too brief to determine the seasonal ranges used by these animals. However, the seasonal home range of RT-2 was estimated as 210 km^2 (Figure 8), based on 22.4 d of movement data. The movements of RT-2, and of other porpoises, indicated that most porpoises exhibit considerable mobility within the study area (see also Gaskin *et al.* 1975). The movements of radio-tagged animals provided no evidence of territoriality or defended areas. The animals appeared to use a portion of their range for a few days, and then shift to another area for a similar period.

At present, the relationship between harbour porpoises in the western Bay of Fundy and those spending the summer in adjacent areas (such as the Gulf of Maine and south-western Nova Scotia) remains unclear. The results of this study and of a previous investigation (Gaskin *et al.* 1975) have provided no evidence that harbour porpoises range outside the study area

during the summer months. Similarly, tagged herring released in the study area are seldom recaptured elsewhere (McKenzie and Skud 1958). However, only limited data on long-term porpoise movements and distribution data are presently available. Longer tracking sequences of a large sample of animals might provide more information regarding the seasonal discreteness of this sub-population.

The brief period of radio contact with tagged animals also precluded determination of the migration routes and overwintering areas of porpoises from the study area. In the western Bay of Fundy, harbour porpoise densities are high only during July, August, and September (Neave and Wright 1968; Gaskin 1977; Read 1983). Although a segment of the population overwinters in the study area, the majority of porpoises appear to be absent from the western Bay of Fundy during other months. The winter distribution of this species in the western North Atlantic is largely unknown, in part because harbour porpoises are difficult objects to sight in rough seas. In the last few years, however, some information has come to light on this subject. Scott Mercer (personal communication) noted that *P. phocoena* was essentially a late fall-early spring element of the cetacean fauna off the coast of New Hampshire, and that porpoises were rarely seen after June. The peak occurrence of this species appeared to be from mid-October until at least January. Poor weather limited fall and winter surveys conducted by the CETAP programme, but the available data suggested that a portion of the population overwinters south of Cape Cod (CETAP 1982). In addition, there are winter strandings from as far south as Virginia and North Carolina (Prescott and Fiorelli 1980).

The overall pattern is strongly suggestive of a single population with a north-south (and inshore-offshore) seasonal migration, limited largely to the continental shelf of the eastern seaboard. The lack of any significant differences in mercury and PCB levels in animals from different parts of this region (Gaskin *et al.* 1979; Gaskin *et al.* 1983) supports the concept of a single population.

HABITAT INDEX

The most distinct trend defined by equations 1 and 2 is the linear increase in harbour porpoise abundance with increasing water depth. Although a preference for deep water has also been

demonstrated for mother-calf pairs of this species (Smith and Gaskin 1983), this is not the sort of trend one would expect from an inshore species. The strong tides encountered in the study area may partially explain this apparent preference. Strong currents often occurred in relatively shallow channels which restricted the flow of water from deeper, less enclosed areas. To remain in such waters for any length of time would be energetically expensive, especially in areas where topographic features caused extensive turbulence. In addition, the daily vertical migration of herring, the primary prey species of porpoises in the area (Smith and Gaskin 1974), may have affected the depth relationship. Herring feed near the surface at night and descend to deeper water during the day (Brawn 1960). Since all observations in this study were made during daylight hours, herring were presumably concentrated in deeper waters whenever transects were run. It should be noted that the defined correlation only applies in waters with depths less than 100 m (the maximum encountered during this phase of the study). It is likely that in waters much deeper than 100 m, many of the factors discussed herein would exert much less influence. Further research in offshore waters is necessary to ascertain the depth at which these factors become unimportant.

In all likelihood, the distribution and abundance of herring are the most important factors affecting the distribution of harbour porpoises in the study area. Although it was impossible to measure the abundance of herring directly (see Watts 1983), the variable *H* represents the presence or absence of specific physiographic features which tend to concentrate herring. Essentially, these areas act as bottle-necks through which large numbers of fish are transported (Jovellanos and Gaskin 1983). Although *H* is only an approximate and indirect indicator of herring distribution, it is strongly correlated with porpoise sightings and is an indispensable component of the habitat index equations. Equations which exclude this variable contain high levels of bias (Watts and Gaskin 1984). More insight into fine-scale distribution of herring is essential for continued progress in the study of harbour porpoise distributional ecology.

The habitat equations also include a significant and negative correlation between porpoise densities and mean August surface water temperatures. This may stem partly from the association of herring with vertically mixed waters

which, due to their mixing, have reduced surface temperatures.

A further equation was derived using data from 15 July to 31 August, when harbour porpoises are most abundant in the region (see above). This equation produces estimates of harbour porpoise density which compare favourably with estimates produced by standard transect procedures. The equation is of the form:

$$Y_2 = 0.0219D + 9.72H - 0.503T + 6.79 \quad (3)$$

This equation has an adjusted r^2 of 0.965 and is significant at $p < 0.0001$ (Watts and Gaskin 1984). The exclusion of data collected prior to 15 July greatly reduces the significance of the depth and temperature components. When applied to the Outer Quoddy region, with a mean depth of 82.72 m (Canadian Hydrographic Service 1981) and a mean August surface water temperature of 11.6°C (L. Murison, University of Guelph, pers. comm.), this equation produces an estimate of 2.8 porpoises·km². This, in turn, produces an estimate of 1022 porpoises in the Outer Quoddy area, compared to estimates of 1018 in 1981 and 1102 in 1982, derived from standard census techniques (see Table 6).

Further discussion of the present habitat index and a comparison with the original study of Smith and Gaskin (1983) may be found in Watts and Gaskin (1984).

POPULATION ESTIMATION

The estimate of population size generated for the study area is obviously a conservative one. No attempt was made to correct for submerged porpoises, and several fairly extensive areas were not surveyed. However, our confidence in this estimate is strengthened by the excellent correspondence between results of habitat index equations and those of standard census techniques.

Our population estimate (3056 porpoises in 1981) also corresponds well with previous estimates made in the study area. Prescott *et al.* (1981), using aerial census techniques, estimated a population of 3456 harbour porpoises in the western Bay of Fundy on 30 August 1980 (see Figure 9). The only other population size estimate made for this region was provided by Gaskin (1977), who used approximate census results to estimate a population of about 4000 individuals in the approaches to the Bay of Fundy. Based on the

results of the present study, this latter estimate would appear to be somewhat lower than the actual value. If the density of porpoises in the areas not covered by the present study is similar to that of the Offshore₂ (Fundy) region (1.15 porpoises·km²), the total number of porpoises in the Bay of Fundy approaches is probably in the order of 7000-8000 animals.

Kraus *et al.* (1983) conducted a ship-board survey of harbour porpoise abundance in the coastal waters of the Gulf of Maine during early July 1982. Analysis of sightings recorded during this survey yielded a minimum population estimate of 7956 porpoises in an area extending from Port Clyde, ME to Cutler, ME. The majority of the harbour porpoise population had not arrived in the western Bay of Fundy while this survey was being conducted, so it seems likely that many of the porpoises recorded by Kraus *et al.* (1983) were still moving northward towards the Bay of Fundy. It seems likely that the majority of the harbour porpoise population which occurs along the eastern seaboard is present in the approaches to the Bay of Fundy during the summer months. Aerial surveys conducted from Cape Hatteras north to the Gulf of Maine indicated that only 1767 porpoises were present in this area during the summer, with the majority of sightings recorded in the Gulf of Maine (CETAP 1982).

The maximum densities of harbour porpoises recorded during this study occurred in Head Harbour Passage during the summer of 1981 (13.33 porpoises·km²). Similar densities were observed in Head Harbour Passage and along the DE-5 transect during the following year. Porpoise densities decreased as one progressed both inshore and offshore from these areas. Low densities have been recorded from the protected waters of Passamaquoddy and Cobscook Bays (Prescott *et al.* 1981; Smith and Gaskin 1983) and from the offshore waters of the Grand Manan Basin (this study). The other regions of relatively high porpoise densities in the study area are off the northern tip of Grand Manan and the Old Proprietor-Bulkhead region to the southeast of Grand Manan.

Observations made from the Grand Manan ferries in all three years of the study, provided no evidence for any change in harbour porpoise abundance (Table 3). In addition, the proportion of calves remained relatively stable around 10% of the total number of porpoises sighted. Continued

observations made from the ferries should provide a cost-effective means of monitoring the abundance of harbour porpoises in the study area during future years.

INCIDENTAL CATCHES

The annual mortality of the harbour porpoise population caused by weirs in the study area appears to be less than 1% of the estimated population size. An unknown number of animals are also trapped in weirs along the northern Maine coast (Prescott and Fiorelli 1980) and a few scattered weirs in western Nova Scotia (Smith *et al.* 1983).

Entanglement in gill nets has a much greater potential for adverse impact on the harbour porpoise population since there is no opportunity for live release. Due to the small number of commercial fishermen actively gill-netting in the study area, however, the mortality associated with this fishery appears to be no greater than that inflicted by herring weirs.

It may also be pertinent to consider recent studies of harbour porpoise-fisheries interactions in New England water, since these animals and those in the Bay of Fundy may, in fact, form portions of a single population (see above). Gilbert and Wynne (1983) recently carried out a study of marine mammal-fishery interactions in this region. Two basic types of set-net operations are conducted; one designed to catch mackerel and the other to catch groundfish. Gilbert and Wynne (*op. cit.*) encountered problems when attempting to estimate effort and reporting reliability, and the number of gill-netters actually operating was, as in Canada, wildly at variance with the number of licences issued. The best estimate of this annual incidental take, mostly by groundfish gill nets in the Gulf of Maine, was approximately 117 small odontocetes (mostly harbour porpoises). The mackerel fishery operating further south, in Cape Cod Bay, also reported by-catches of odontocetes, but the majority of these entanglements proved to be white-sided dolphins.

Evidence of a significant incidental catch was reported by S. Mercer (1983, pers. comm.), who noted a large by-catch of harbour porpoises in gill nets in the vicinity of Jeffrey's Ledge (42°52'N 70°24'W) and Old Scantum's Ledge (42°55'N 70°25'W) between October and December. Mercer's informal interviews, coupled with his own records from gill-netting, suggested

that as many as 30-40 porpoises per week were being killed during this period, for a total of perhaps 300-400 animals. This estimate did not include mortality incurred during the spring fishing season.

Records of strandings along the Virginia and North Carolina coasts have already been discussed in the Radio Tracking section. These stranded animals may have been caught and then discarded by fishing vessels, since porpoises consistently washed ashore in the vicinity of discarded fish (J. Mead 1983, personal communication). No estimate of this incidental catch has been made on an annual basis and this catch may represent an unusual occurrence during a single winter (1976-1977), when harbour porpoises were further south than usual.

SYNOPSIS

Radio-tagged harbour porpoises demonstrated considerable mobility within the western Bay of Fundy. However, there was no evidence that these porpoises travelled outside the study area during their brief tracking periods. The tracking periods of radio-tagged porpoises were too brief to determine the annual migrations of these animals, although indirect evidence supports the concept of a single population with a combined north-south and inshore-offshore migration along the continental shelf of the eastern seaboard.

Habitat index analysis techniques were used to correlate the abundance of harbour porpoises in the study area to a variety of environmental variables. Porpoise abundance was positively correlated with increasing depth, and with physiographic features that may concentrate herring in surface waters. Abundance was inversely correlated with mean August surface water temperatures. These correlations appear to reflect the importance of the distribution and abundance of herring as a factor affecting the distributional ecology of harbour porpoises in the study area.

Strip transect surveys were used to generate a minimum population estimate of 3056 porpoises in the western Bay of Fundy in the late summer of 1981. This estimate corresponds well with estimates derived from aerial surveys. These data suggest that a large proportion of the harbour porpoise population present along the eastern seaboard utilizes the western bay of Fundy during the summer months.

Approximately 1% of the estimated population of porpoises in the study area are killed after becoming trapped in herring weirs each year. A more serious threat to the population is posed by gill nets in the waters of coastal New England, through which a large proportion of the population apparently passes while migrating during both the autumn and spring. The magnitude of this incidental catch has not yet been determined.

It is difficult to provide any concrete recommendations to management approaches for this population, especially in view of our limited knowledge of much of the species' life history (see Gaskin et al. 1984). However, the recent collapse of the Baltic and Black Sea harbour porpoise populations should encourage a conservative management approach. Serious attempts should be made to reduce the magnitude of incidental catches in all areas of the population's range and to improve our knowledge of reproductive parameters by effectively sampling these by-catches.

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REFERENCES

- Brawn, V.M. 1960. Seasonal and diurnal vertical distribution of herring (Clupea harengus L.) in Passamaquoddy Bay, N.B. J. Fish. Res. Board Can. 17:699-711.
- Brown, R.G.B. 1980. Seabirds as marine animals. Pages 1-39 in Burger, J., B.L. Olla, and H.E. Winn (editors). Behavior of Marine Animals, Volume 4. Plenum Press, New York.
- Brown, R.G.B., S.P. Barker, and D.E. Gaskin. 1979. Daytime surface swarming by Meganycetiphanes norvegica (M. Sars) (Crustacea, Euphausiacea) off Brier Island, Bay of Fundy. Can. J. Zool. 57:2285-2291.
- Canadian Hydrographic Service. 1981. Nautical Chart 4011.
- CETAP. 1982. A characterization of marine mammals and turtles in the Mid- and North Atlantic areas of the U.S. Outer Continental Shelf. Final Report of the Cetacean and Turtle Assessment Program. U.S. Dept. of the Interior, Bureau of Land Management. 450 pp.
- Eberhardt, L.L., D.G. Chapman, and J.R. Gilbert. 1979. A review of marine mammal census methods. Wildl. Monogr. No. 63. 46 pp.
- Forrester, W.D. 1958. Current measurements in Passamaquoddy Bay and the Bay of Fundy, 1957-1958. Tidal Publ. 40, Dept. Mines and Technical Surveys, Ottawa. 73 pp.
- Gaskin, D.E. 1977. Harbour porpoise, Phocoena phocoena (L.), in the Bay of Fundy 1969-1975. Rep. Int. Whal. Commn. 27:487-492.
- Gaskin, D.E. 1984. The harbour porpoise Phocoena phocoena (L.): regional populations, status, and information on direct and indirect catches. Rep. Int. Whal. Commn. 34: In Press.
- Gaskin, D.E., R. Frank, and M. Holdrinet. 1983. Polychlorinated biphenyls in harbour porpoises Phocoena phocoena (L.) from the Bay of Fundy, Canada and adjacent water, with some information on chlordane and hexachlorobenzene levels. Arch. Environ. Contam. Toxicol. 12:211-219.
- Gaskin, D.E., and G.J.D. Smith. 1979. Observations on marine mammals, birds and environmental conditions in the Head Harbour region of the Bay of Fundy. Pages 69-86 in Scarratt, D.J. (editor). Evaluation of recent data relative to potential oil spills in the Passamaquoddy area. Can. Fish. Mar. Serv. Tech. Rep. No. 901. 107 pp.

- Gaskin, D.E., G.J.D. Smith, and A.P. Watson. 1975. Preliminary study of movements of harbour porpoises (Phocoena phocoena) in the Bay of Fundy using radiotelemetry. *Can. J. Zool.* 53:1466-1471.
- Gaskin, D.E., G.J.D. Smith, A.P. Watson, W.Y. Yasui, and D.B. Yurick. 1984. Reproduction in the porpoises (Phocoenidae, Cetacea): implications for management. *Rep. Int. Whal. Commn.* (Special Issue 6):324-352.
- Gaskin, D.E., K.I. Stonefield, P. Suda, and R. Frank. 1979. Changes in mercury levels in harbour porpoises from the Bay of Fundy, Canada, and adjacent waters during 1969-1977. *Arch. Environm. Contam. Toxicol.* 8:733-762.
- Gilbert, J.R., and K.M. Wynne. 1983. Harbor seal populations and marine mammal-fisheries interactions, 1982. Second Annual Report, Contract NA-80-FA-00029. Northeast Fisheries Center, NMFS, U.S. Dept. of Commerce, Woods Hole, MA. 43 pp.
- Greenberg, D.A. 1979. A numerical model investigation of tidal phenomena in the Bay of Fundy and Gulf of Maine. *Marine Geodesy* 2:161-187.
- Hui, C.A. 1979. Underwater topography and distribution of dolphins of the genus Delphinus in the southern California bight. *J. Mamm.* 60:521-527.
- Jovellanos, C.L., and D.E. Gaskin. 1983. Predicting the movements of juvenile Atlantic herring (Clupea harengus harengus) in the SW Bay of Fundy using computer simulation techniques. *Can. J. Fish. Aq. Sci.* 40:45-53.
- McKenzie, R.A., and B.E. Skud. 1958. Herring migrations in the Passamaquoddy region. *J. Fish. Res. Board Can.* 17:133-168.
- Mohr, C.O. 1947. Table of equivalent populations of North American small mammals. *Amer. Midl. Nat.* 37:223-249.
- Neave, D.J., and B.S. Wright. 1968. Seasonal migrations of the harbour porpoise (Phocoena phocoena) and other Cetacea in the Bay of Fundy. *J. Mammal.* 49:259-264.
- Prescott, J.H., and P.M. Fiorelli. 1980. Review of the harbor porpoise (Phocoena phocoena) in the U.S. northwest Atlantic. PB80-176928 NTIS, Springfield, VA.
- Prescott, J.H., S.D. Kraus, P. Fiorelli, D.E. Gaskin, G.J.D. Smith, and M. Brander. 1981. Harbor porpoise (Phocoena phocoena): distribution, abundance, survey methodology and preliminary notes on habitat use and threats. Final report to the U.S. Dept. of Commerce, Contract NA-80-FA-00009. 61 pp.
- Read, A.J. 1983. Movements and distribution of harbour porpoises, Phocoena phocoena (L.), in the western Bay of Fundy. M.Sc. Thesis, University of Guelph. 83 pp.
- Read, A.J., and D.E. Gaskin. 1983. The application of radio tracking techniques to the study of harbour porpoises (Phocoena phocoena) in the Bay of Fundy. Pages 346-352 in Pincock, D.G. (editor). *Proceedings of Fourth Intl. Wildlife Biotelemetry Conference.* Halifax.
- Read, A.J., and D.E. Gaskin. 1984. Radio tracking the movements and activities of harbour porpoises, Phocoena phocoena (L.), in the Bay of Fundy, Canada. Submitted to *Fish. Bull.*
- Sergeant, D.E., A.W. Mansfield, and B. Beck. 1970. Inshore records of Cetacea for eastern Canadian waters. *J. Fish. Res. Board Can.* 27:1903-1915.
- Smith, G.J.D., and D.E. Gaskin. 1974. The diet of harbour porpoises (Phocoena phocoena (L.)) in coastal water of eastern Canada, with special reference to the Bay of Fundy. *Can. J. Zool.* 52:777-782.
- Smith, G.J.D., and D.E. Gaskin. 1983. An environmental index for habitat utilization by female harbour porpoises with calves near Deer Island, Bay of Fundy. *Ophelia* 22:1-13.
- Smith, G.J.D., C.L. Jovellanos, and D.E. Gaskin. 1984. Near-surface bio-oceanographic phenomena in the Quoddy region, Bay of Fundy. *Can. Tech. Rep. Fish. Aq. Sci.* In Press.

Smith, G.J.D., A.J. Read, and D.E. Gaskin. 1983. Incidental catch of harbor porpoise, Phocoena phocoena (L.), in herring weirs in Charlotte County, New Brunswick, Canada. Fish. Bull. 81:660-662.

Trites, R.W. 1979. Comments on flushing time for Passamaquoddy Bay and wind-generated waves in the Quoddy region. Pages 3-7 in Scarratt, D.J. (editor). Evaluation of recent data relative to potential oil spills in the Passamaquoddy area. Can. Fish. M-r. Serv. Tech. Rep. No. 901.

Watts, P.F. 1983. Habitat index analysis of inshore distribution of Phocoena phocoena in the Bay of Fundy. M.Sc. Thesis, University of Guelph. 92 pp.

Watts, P.F., and D.E. Gaskin. 1984. Habitat index analysis of harbour porpoise (Phocoena phocoena L.) in the southern coastal Bay of Fundy, Canada. Submitted to J. Mammal.

Table 1. Data summary for harbour porpoises tagged and released in the western Bay of Fundy. Porpoise code refers to the type of tag used: RT denotes radio tag and FT denotes fin tag.

Porpoise Code	Length (cm)	Sex	Frequency (MHz)	Date of Release	Duration of Contact (d)
RT-1	132	M	173.350	05 08 81	3.05
RT-2	119	M	173.550	20 08 81	22.4
RT-3	145	M	173.500	29 07 82	5.32
RT-4	131	F	173.100	31 08 82	3.16
FT-1	101	M	-	31 08 82	-
RT-5	114	M	173.000	31 08 82	0.30
RT-6	116	M	173.700	01 09 82	2.72
RT-7	110	M	173.650	03 09 82	1.83
RT-8	114	M	172.600	09 08 83	2.25
FT-2	93	M	-	10 08 83	-

Table 2. Mean densities of inshore transects in the Deer Island and Grand Manan regions surveyed during 1981 and 1982. Densities are represented by porpoises/km². The number of transects run each season is denoted by N.

Transect	1981				1982			
	X	±	SD	(N)	X	±	SD	(N)
DE-1	1.09	±	2.59	(11)	0.00	±	0.00	(7)
DE-2	0.62	±	2.22	(13)	0.00	±	0.00	(3)
DE-3	3.67	±	6.02	(12)	2.29	±	3.90	(7)
DE-4	13.32	±	14.2	(12)	10.67	±	12.0	(9)
DE-5		±		(0)	12.94	±	14.8	(17)
GM-1	1.82	±	4.85	(11)	2.00	±	4.97	(12)
GM-2	0.00	±	0.00	(12)	1.33	±	3.11	(12)
GM-3	0.00	±	0.00	(8)	0.67	±	1.63	(6)

Table 3. Harbour porpoise densities observed along the Grand Manan ferry route during 1981-1983. Densities are presented in porpoises/km². N represents the number of completed surveys. T represents the total number sighted within the 200 m strip, and C denotes the number of calves.

Year	N	T (C)	X $\pm$ S.D.
1981	5	95 (12)	2.79 $\pm$ 2.34
1982	14	270 (29)	3.02 $\pm$ 1.30
1983	10	228 (21)	3.48 $\pm$ 3.13

Table 4. Data summary for surveys made in the Outer Quoddy region by observers aboard the MV "Miss Michelle." Numbers of porpoises sighted (T) refers to the number observed within a 100 m strip (50 m on either side of vessel). C refers to the number of calves observed during each transect. See Figure 6 for transect locations.

Date	Transect	Length of Trackline (km)	T (C)
27 07 83	A-3	8.9	0 (0)
	A-8	11.4	10 (2)
	B-1	12.7	3 (0)
	B-8	12.2	12 (2)
04 08 83	A-6	10.9	6 (2)
	A-10	11.4	13 (0)
	B-5	11.9	5 (1)
	B-10	13.5	0 (0)
	C-1	13.0	2 (0)
	C-8	13.8	0 (0)
05 08 83	A-7	10.9	1 (0)
	B-2	12.2	2 (0)
	B-7	11.1	0 (0)
	C-2	14.9	3 (1)
Total		168.8	57 (8)

Table 5. Data summaries for harbour porpoise surveys conducted in the offshore region of the western Bay of Fundy by observers aboard the MV "Pat & Robbie." The number of porpoises sighted (T) refers to the number observed within a 100 m strip (50 m on either side of the vessel). C refers to the number of calves sighted. See Figure 7 for location of survey routes followed each year.

Date	Length of Trackline (km)	T (C)
20 08 81	75	2 (0)
21 08 81	47	20 (1)
28 08 81	67	1 (0)
01 09 81	45	4 (0)
Total	234	27 (1)
25 07 83	67	0 (0)
04 08 83	71	6 (2)
07 08 83	77	0 (0)
10 08 83	56	0 (0)
14 08 83	55	39 (0)
18 08 83	20	6 (0)
03 09 83	73	0 (0)
05 09 83	71	3 (1)
Total	490	54 (3)

Table 6. Estimated size of the harbour porpoise population in the western Bay of Fundy in 1981. CL refers to 95% confidence limits around each estimate.

Region	Area (km ²)	Estimate $\pm$ CL
Deer Island	250	614 $\pm$ 161
Grand Manan	147	36 $\pm$ 17
Outer Quoddy	365	1018 $\pm$ 336
Offshore (Fundy)	1207	1388 $\pm$ 1147
Total	1969	3056 $\pm$ 1661

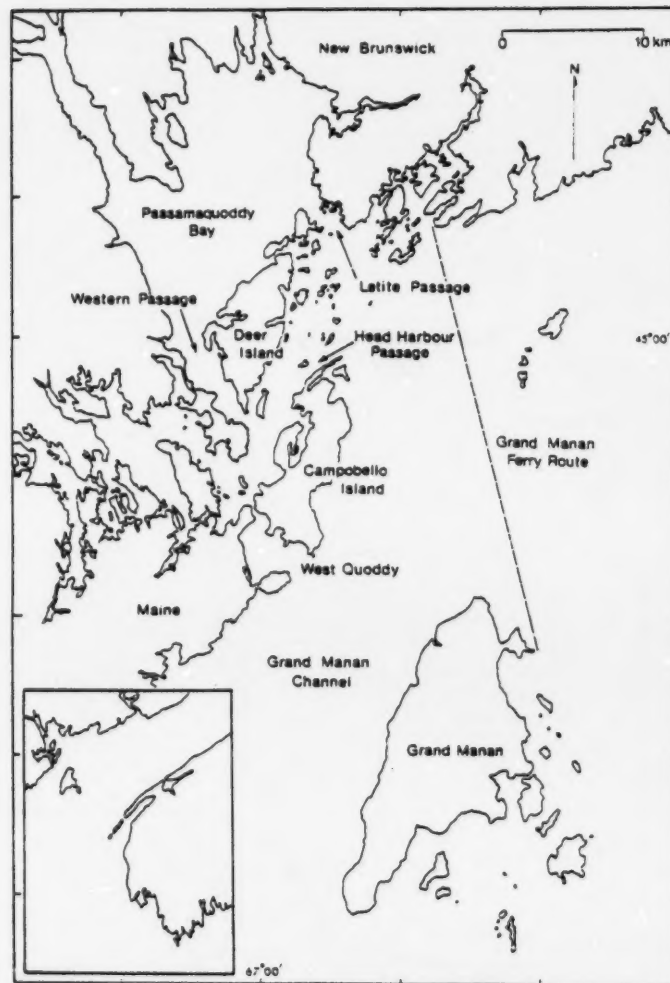


Figure 1. The western Bay of Fundy, with place names mentioned in text. The inset depicts the study area in relation to the rest of the Bay of Fundy.

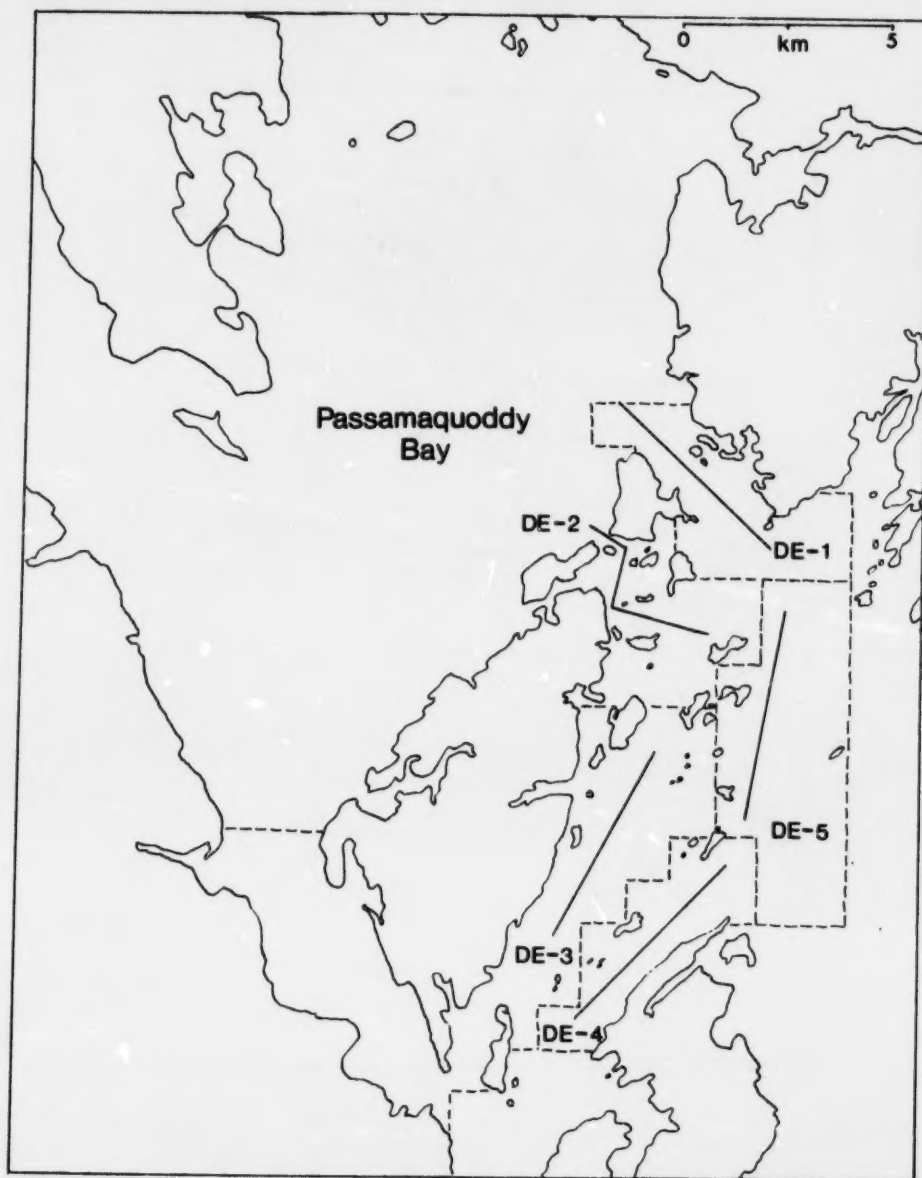


Figure 2. Location of transects run in the Deer Island region, New Brunswick. The harbour porpoise density observed along each transect was used to estimate the density of porpoises within each sub-area (designated by broken lines).

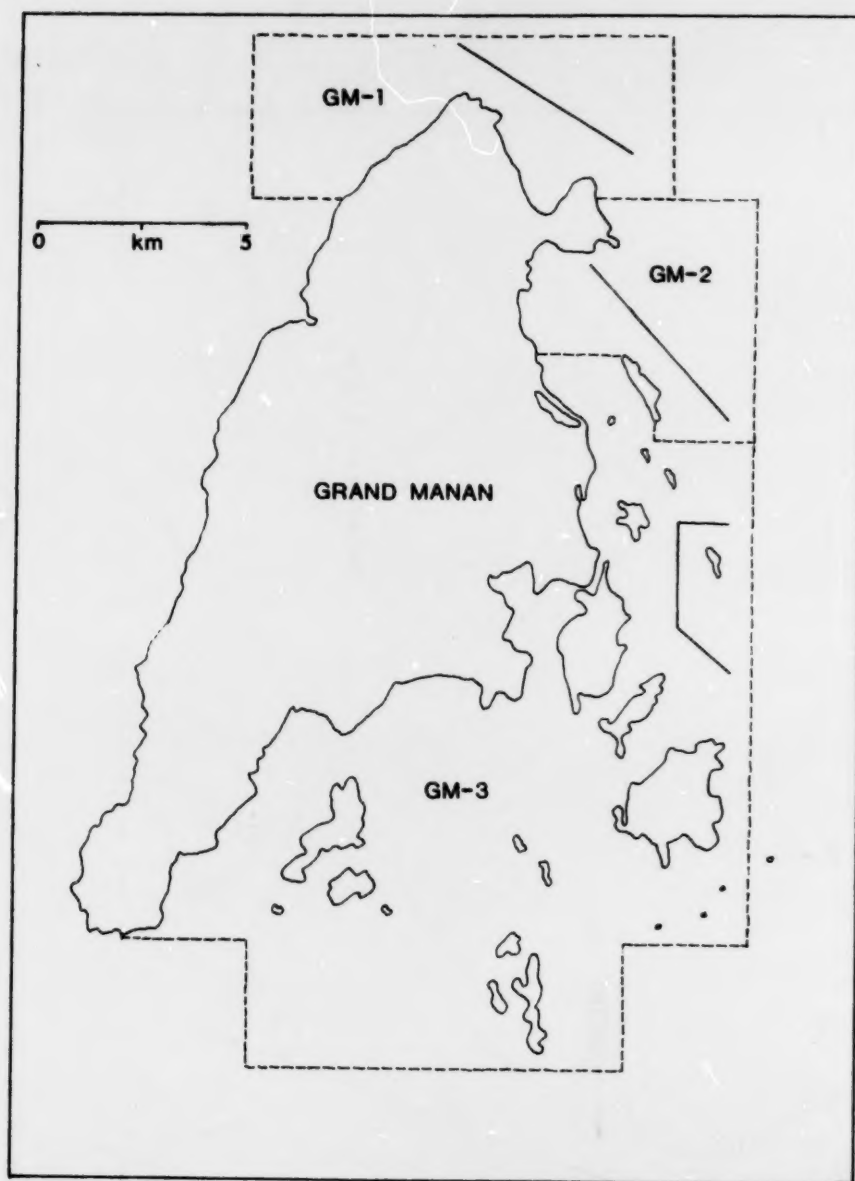


Figure 3. Location of transects run in the Grand Manan region, New Brunswick. The harbour porpoise density observed along each transect was used to estimate the density of porpoises within each sub-area (designated by broken lines).

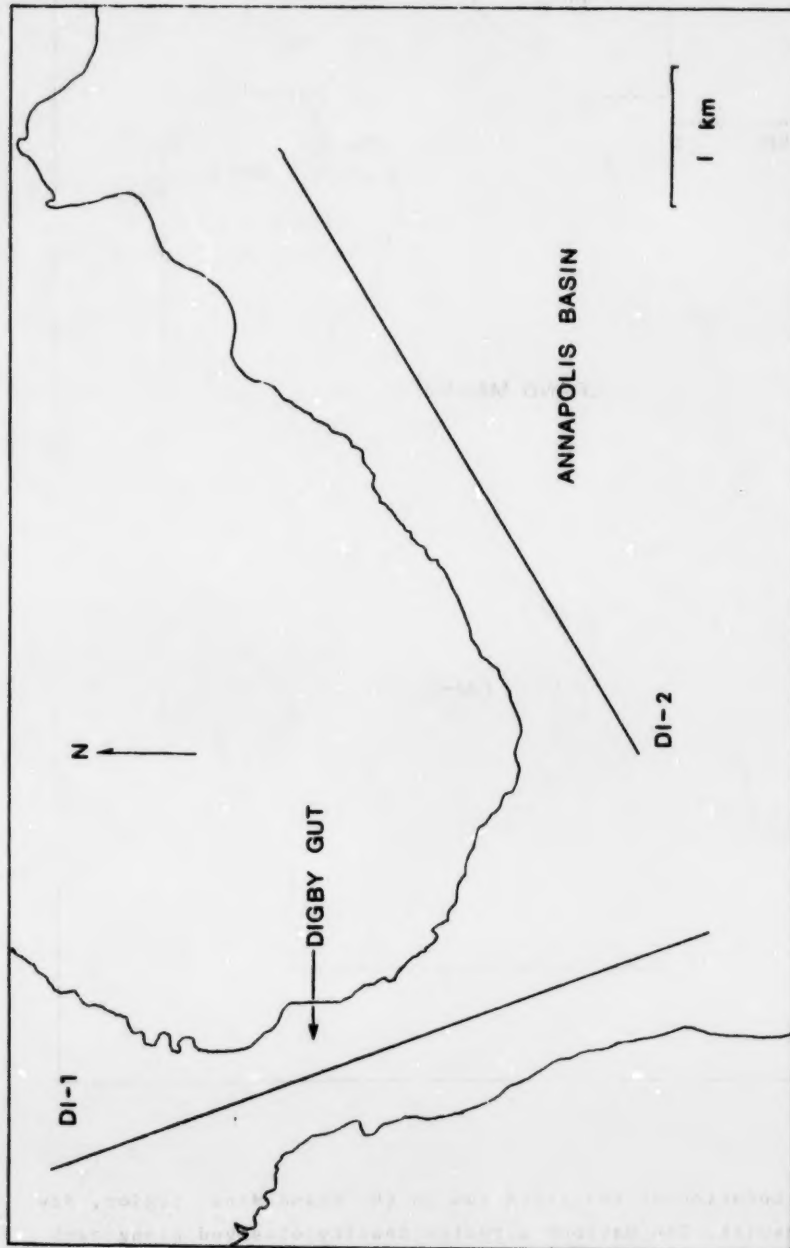


Figure 4. Location of transects run in the Digby, Nova Scotia region.

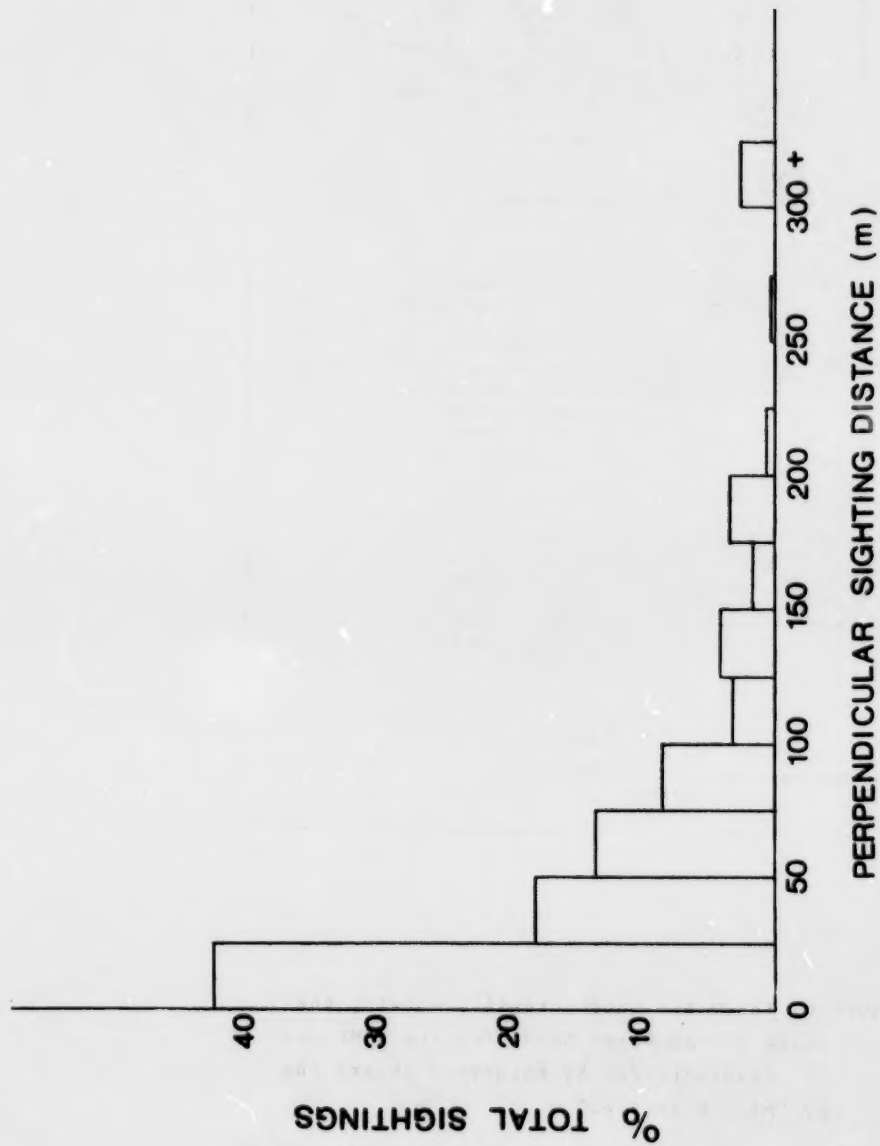


Figure 5. Frequency histogram of observed perpendicular sighting distances observed during harbour porpoise surveys in the inshore waters of Deer Island, Grand Manan and Digby. N = 276.

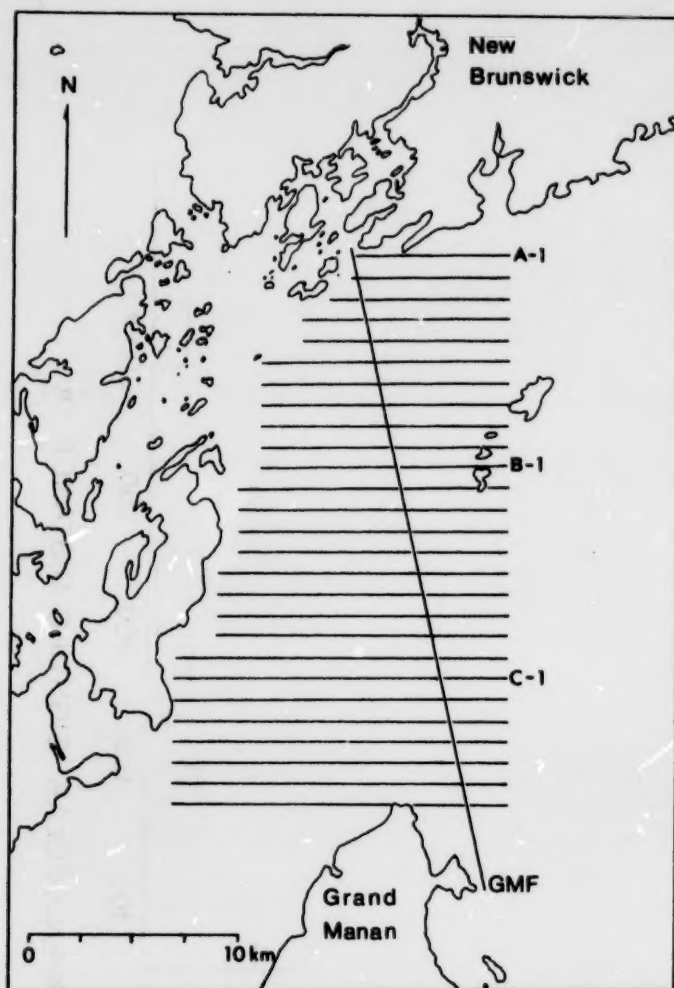


Figure 6. The Outer Quoddy region, showing the route of the Grand Manan ferries (GMF) and the transects run by observers aboard the MV "Miss Michelle."

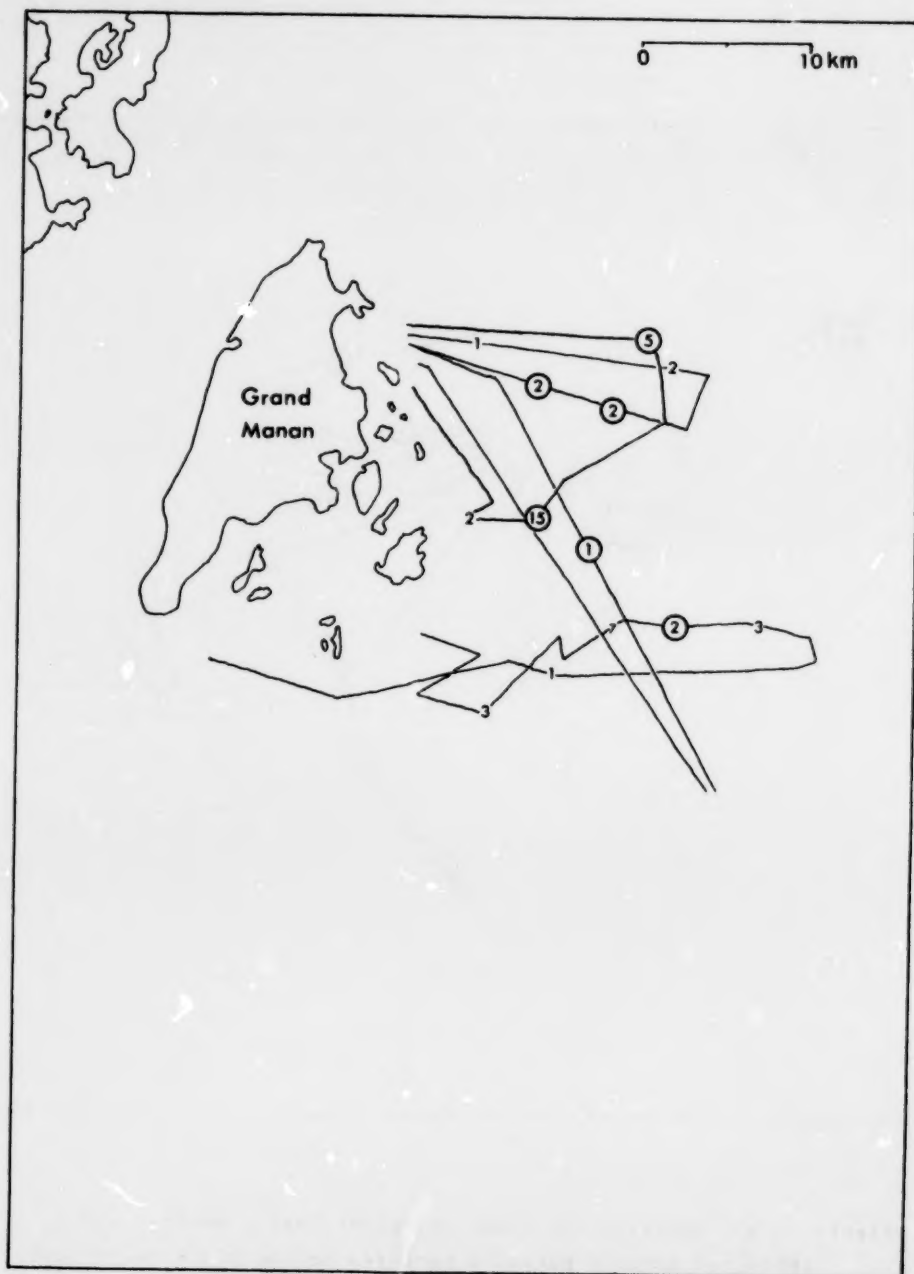


Figure 7 (a). Survey track lines of the MV "Pat & Robbie" which conducted harbour porpoise censuses in the Offshore (Fundy) region in 1981. Porpoise sightings are indicated by numerals denoting the number sighted. Circled numerals indicate that a sighting was made within the 100 m strip.

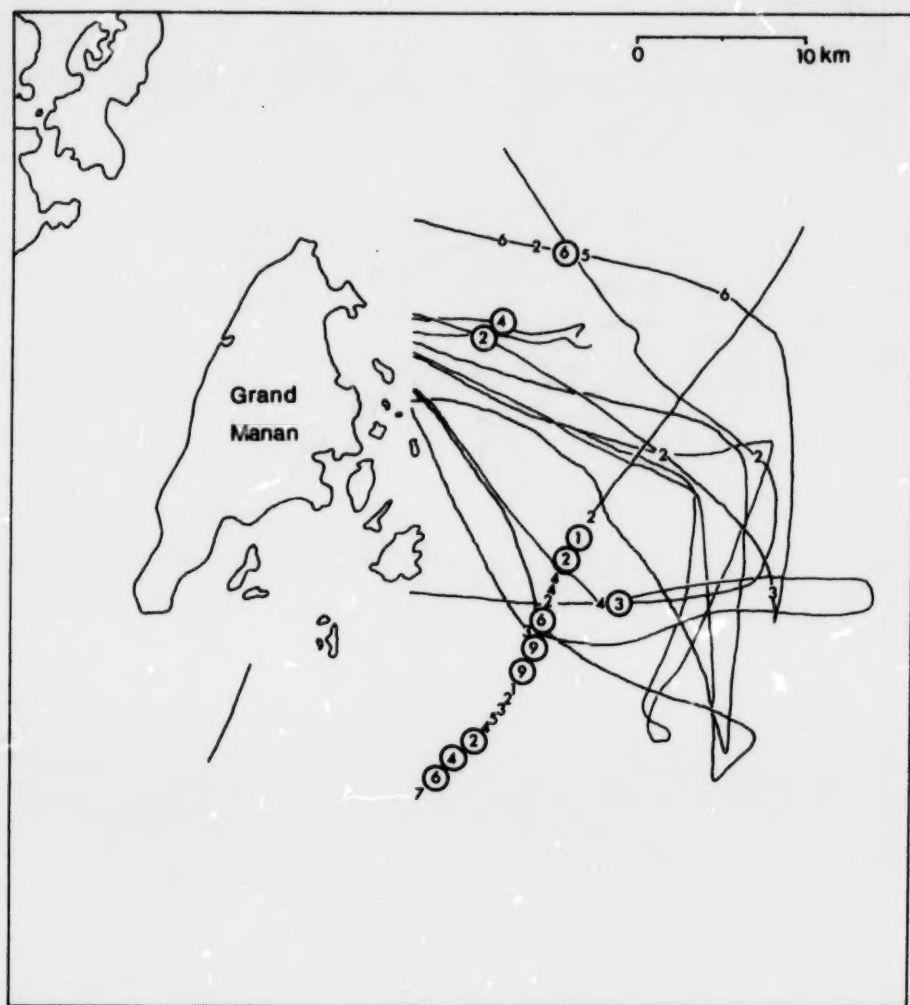


Figure 7 (b). Survey track lines of the MV "Pat & Robbie" which conducted harbour porpoise censuses in the Offshore (Fundy) region in 1983. Porpoise sightings are indicated by numerals denoting the number of porpoises in each sighting. Circled numerals indicate that sightings were made within the 100 m strip.

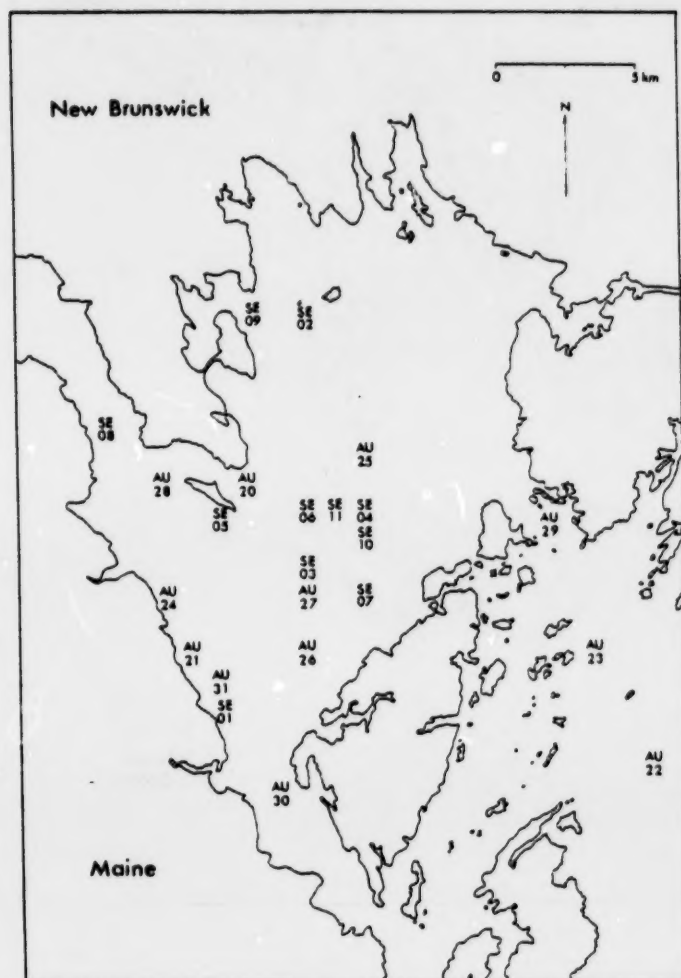


Figure 8. Position of radio-tagged harbour porpoise RT-2 at 1200 on each day of tracking period in the western Bay of Fundy.

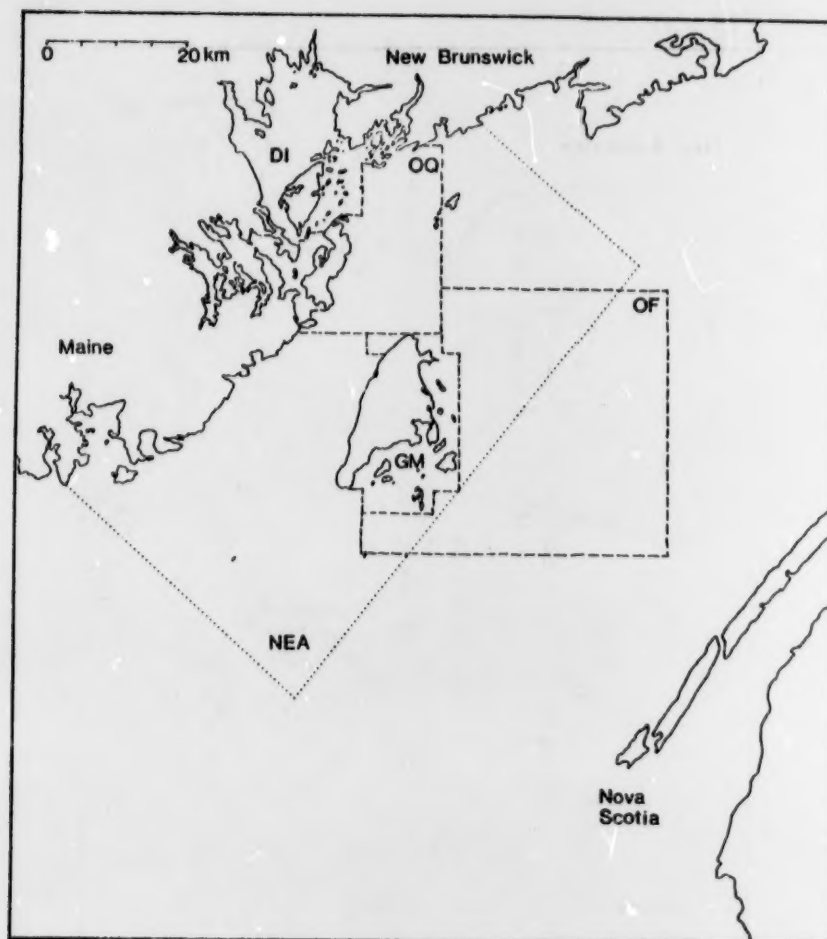


Figure 9. Delineation of regions used in population estimation procedures. Four regions were examined in the present study: Deer Island (DI), Grand Manan (GM), Outer Quoddy (OQ), and Offshore Fundy (OF). For comparative purposes the survey area (NEA) of Prescott *et al.* (1981) is indicated by a dotted line.